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WORKBOOK OF SCREENING TECHNIQUES FOR ASSESSING IMPACTS OF TOXIC AIR POLLUTANTS (REVISED)

Office of Air Quality Planning and Standards
Office of Air and Radiation
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

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PREFACE

This document supersedes the workbook version dated September 1988. Changes include: development of new methods for estimating emission rates; revisions to methods for esitmating emission rates to establish consistency with current guidance; addition of several new scenarios, especially those related to Superfund; and the addition of a new screening method based on the work of Britter and McQuaid to estimate the impact of aerosols and denser-than-air gases released from chemical spills. Ambient concentrations are now illustrated by using the TSCREEN model instead of hand calculations. Thus, users comparing the predicted maximum ground level concentrations with those shown in the earlier document will now find different, and more accurate, estimates.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

This workbook provides a logical approach to the selection of appropriate screening techniques for estimating ambient concentrations due to various toxic/hazardous pollutant releases. Methods used in the workbook apply to situations where a release can be fairly well-defined, a condition typically associated with non-accidental toxic releases. The format of this workbook is built around a series of release scenarios which may be considered typical and representative of the means by which toxic chemicals become airborne. This document supersedes the earlier workbook (EPA, 1988a).

Screening techniques are simplified calculational procedures designed with sufficient conservatism to allow a determination of whether a source: 1) is clearly not an air quality threat or 2) poses a potential threat which should be examined with more sophisticated estimation techniques or measurements. Screening estimates obtained using this workbook represent maximum short-term ground level concentration estimates from a meteorological perspective. If the screening estimates demonstrate that during these conditions the ground level concentrations are not likely to be considered objectionable, further analysis of the source impact would not be necessary as part of the air quality review of the source. However, if screening demonstrates that a source may have an objectionable impact, more detailed analysis would be required using refined emissions and air quality models.

For each release scenario, the workbook describes the procedure to be used and provides an example illustration using the TSCREEN model. TSCREEN, a model for screening toxic air pollutant concentrations, is an IBM PC-based interactive model that implements the release scenarios and methods described in this workbook. TSCREEN allows the user to select a scenario, determine an emission rate, and then apply the appropriate dispersion model in a logical problem solving approach. The model consists of a front-end control program with many interactive menus and data entry screens. As much information as is logically and legibly possible is assembled onto unique data entry screens. All requests for input are written in clear text. Extensive help screens are provided to minimize numeric data entry errors, and default values are provided for some parameters. The user is able to return to previous screens and edit data previously entered. A chemical look-up database and an on-line calculator are also available. Once the nature of the release is determined, the user must specify the emission rate. For some scenarios, extensive references to EPA methods are provided, while for others, a specific method for calculating the emission rate is given. Density checks for the release are performed to determine which dispersion model is selected. Data necessary to execute that particular model is then requested in a logical format. Once the model is executed, the concentrations are calculated and then tabulated in a clear and legible manner, and an easy to read graph of concentration versus distance is provided. The printed text and graphical output can be sent to a variety of printers and plotters through built-in software; minimum user interface is required.

The front-end program in TSCREEN is written in the FoxPro™ programming language, a superset of the dBASE language family suitable for PC's running MS-DOS™. The primary purpose of a dBASE language is database manipulation, but is can also be used for general purpose programming. The reasons for using this system are: 1) a user interface which facilitates the debugging process, and as a result, reduces the development cost; 2) pull-down menus and windows which require minimal programming effort to create; 3) built-in functions for database manipulation, and as a result, much less code is required to create the chemical database in TSCREEN; 4) memory management capabilities that allow TSCREEN to run on machines with less random access memory (RAM); and 5) the ability to release most of the TSCREEN front-end program from memory before it executes the dispersion models. The main disadvantage of this system is the size of the files that a user needs to run. The system is distributed with two run-time libraries. These are files that contain the implementation of functions that are called by the program. One of these libraries is over 300 kilobytes (K) and the other is close to 1 megabyte (MB). TSCREEN is distributed through the EPA's Technology Transfer Network, SCRAM Bulletin Board System.

The workbook is organized into five sections and six supporting appendices. Section 2 discusses selection of screening techniques and the general approach to using the workbook. Users are advised to consult this section both for releases explicitly presented in the workbook and for less typical releases. This section also considers assumptions, limitations and conservatism of estimates. Section 3 describes the support data (i.e., meteorological data and chemical and physical parameters) needed for making estimates. Section 4 presents the inputs required for each scenario and the applicable methods for determining release (emission) rates. This section also includes an example showing the data entry screening and sample calculations for each scenario as used in TSCREEN. (Note: the values that TSCREEN produces may be slightly different than the values in the examples due to differences in rounding.) In this workbook 24 release scenarios have been selected to represent situations likely to be encountered. Section 5 describes the dispersion models that are referenced in this workbook and are embedded in TSCREEN.

Appendix A discusses currently available sources for obtaining emission factors that can be used for some of the scenarios. Appendix B provides a method for estimating selected physical properties for mixtures. Appendix C provides some useful unit conversion factors applicable to the workbook.

Appendix D provides some techniques for converting concentrations calculated by the models to different averaging times.

Methods used in this workbook should be applied with caution. Techniques for estimating emissions are evaluated and revised on a continuing basis by EPA. Thus the user should consult with EPA on the most recent emission models and emission factors. Meteorological methods presented in this workbook reflect guidance published elsewhere, and in particular the Guideline on Air Quality Models (Revised) (EPA, 1986) and its supplements. The Regional Modeling Contact should be consulted as to the present status of guidance on air quality modeling.

2.0 SELECTION OF SCREENING TECHNIQUES FOR TOXIC AIR CONTAMINANTS

This workbook attempts to account for many of the scenarios expected to produce toxic chemical releases to the atmosphere.

2.1 Release Categorization

Selection of appropriate technique for screening estimates requires categorization of the toxic chemical release of interest. There are three overlapping categories which should be considered when defining problems for screening:

1) Physical State - Gaseous releases to the atmosphere can, in general, be simulated using techniques developed for criteria air pollutants unless the gas is dense, is highly reactive, or rapidly deposits on surfaces. Additional source modeling must be performed if the release is liquid, aerosol or multi-phased to determine the state of the material as it disperses in air.

2) Process/Release Conditions - Knowledge of the circumstances under which chemicals are released helps to determine both state and dispersive characteristics. For example, location of a leak in a pressurized liquefied gas storage tank will determine if a release is liquid or gas and if source modeling is required prior to dispersion estimates.

3) Dispersive Characteristics - Techniques for pollutant dispersion estimates are categorized by terms such as instantaneous versus continuous, or point versus area or volume releases. To complete dispersion estimates, this final characterization is required at some point in concentration calculations.

The primary emphasis of this workbook is to serve as an accompanying guide to the TSCREEN program which implements screening techniques for estimating short-term, ground level concentrations of toxic chemicals released to the atmosphere. However, in order to do this, the workbook also provides assistance to the user in formulating the release conditions.

2.2 Limitations and Assumptions

Methods included in TSCREEN are intended to provide simplified screening estimates for situations which may represent extremely complex release scenarios. As such, the methods are limited in their applicability. Some of these limitations are as follows:

- Screening techniques provided are intended for use on small to mid-scale non-accidental releases.

- All techniques assume that the toxic air contaminant is non- reactive and non-depositing. Thus these screening methods are not applicable for reactive gases and particle depositions. For two-phase flows, all released liquid is assumed to travel downwind as an aerosol with insignificant (liquid) rain out near the source.

- Denser-than-air contaminant behavior is a consequence not only of the initial (depressurized) contaminant density but also of the contaminant release rate and the ambient wind speed; if denser-than-air contaminant behavior is not expected to be important, passive atmospheric dispersion modeling techniques should be applied. In TSCREEN Version 3.0, the determination of denser-than-air behavior is done based on the initial contaminant density comparison to ambient air.

- Conditions resulting in worst case concentrations cannot be uniquely defined where meteorological conditions affect source estimates. For example, in the case of evaporation, the highest emission rates are related to high wind speeds, which, however, result in more dilution and lower ambient concentrations.

- Time dependent emissions cannot be simulated with these simple screening technique. Techniques provided assume steady releases for a specified period.

- All release calculations assume ideal conditions for gas and liquid flows.

- The influence of obstructions such as buildings and topography on denser-than-air releases and releases close to the ground are not included.

- Complicated post-release thermodynamic behavior for denser-than-air releases is not accounted for in these screening techniques.

Because of the simplifying assumptions inherent in these screening methods, which are specifically aimed at decreasing the amount of information required from the user and decreasing the computation time and sophistication, more refined assessment techniques should be applied to a release scenario which is identified by these screening procedures as violating ambient air quality standards or other specified levels of concern. Refined techniques involve both refined release (emission) rate estimates as well as more refined atmospheric dispersion models. (See for example, "Guidance on the Application of Refined Dispersion Models for Air Toxics Releases" (EPA, 1991a).) As with any air quality assessment, the screening methods described here should be applied with due caution.

2.3 Scenario Selection

Release scenarios are grouped according to four categories: particulate matter, gases, liquids, and releases from Superfund sites as shown in Table 2-1. For some of the categories, there are additional subcategories. Figure 2-1 provides a graphical illustration of each release scenario. Descriptions on similar release scenarios are provided to help guide the user in selecting the correct release category. Once the correct release category has been selected, the user should proceed to the relevant section where further information on the release scenario is given. For each release scenario, methods for determining emission estimates are provided and then the appropriate dispersion model is selected to determine ambient concentrations.

TABLE 2-1
RELEASE SCENARIOS

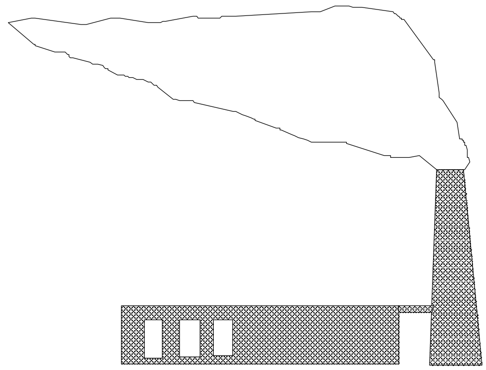
Initial Form of Release	Release Type	Scenario Number	Modeling Category *
Particulate Matter	Continuous Particulate Release from Stack, Vents	1.1	CP
	Fugitive/Windblown Dust Emissions	1.2	CA
	Ducting/Connector Failures	1.3	IP
Gases	Flared Stack Emissions	2.1	CP
	Continuous Releases from Stacks, Vents, Point Sources	2.2	CP
		2.3	CP
	Continuous Leaks from Reservoir	2.4	IP
	Instantaneous Leak from Reservoir	2.5	CP
	Continuous Leaks from Pipe Attached to Reservoir	2.6	IP
	Instantaneous Leak from Pipe Attached to Reservoir	2.7	CA
	Gaseous Emissions from Multiple Fugitive Sources	2.8	CA
	Gaseous Emissions from Land Treatment Facilities	2.9	CA
	Emissions from Municipal Solid Waste Landfills	2.10	CA
	Emissions from Pesticides/Herbicide Applications	2.11	IP
	Discharges from Equipment Openings		
Liquid	Evaporation from Surface Impoundments (Lagoons)	3.1	CA
	Continuous 2-Phase Saturated Liquid from Pressurized Storage	3.2	CP
		3.3	IP
	Instantaneous 2-Phase Saturated Liquid from Pressurized Storage	3.4	CP
		3.5	IP
	Continuous 2-Phase Subcooled Liquid from Pressurized Storage	3.6	CP
		3.7	IP
	Instantaneous 2-Phase Subcooled Liquid from Pressurized Storage	3.8	CA
		3.9	IP
	Continuous High Volatility Liquid Leaks		
	Instantaneous High Volatility Liquid Leaks		
	Continuous Low Volatility Liquid Leaks		
	Instantaneous Low Volatility Liquid Leaks		
Superfund Sites	Air Stripper	4.1	CP

* C - Continuous
P - Point
A - Area
I - Instantaneous

Table 2-1 shows that, for example, a continuous gaseous release from stacks, vents and point sources is given Scenario number 2.2. Figure 2-1 provides a graphical illustration and a brief description of this scenario. Figure 2-2 (Section 2.4) shows that this scenario is discussed in detail in Section 4.2.2 and that the SCREEN dispersion model is selected within TSCREEN to estimate ambient ground level concentrations for this scenario.

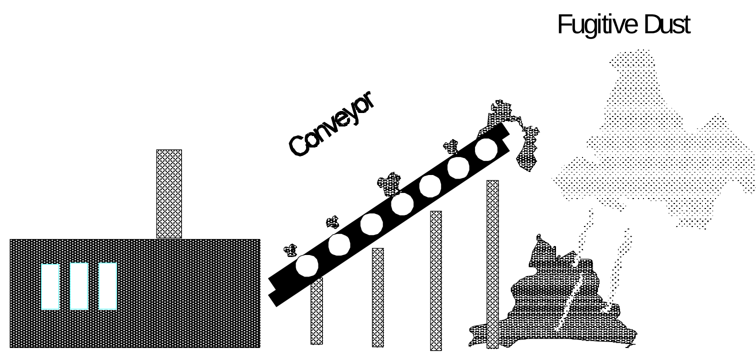
Figure 2-1. Schematic Illustrations of Scenarios

Continuous Releases of Particulate Matter from Stacks, Vents -1.1



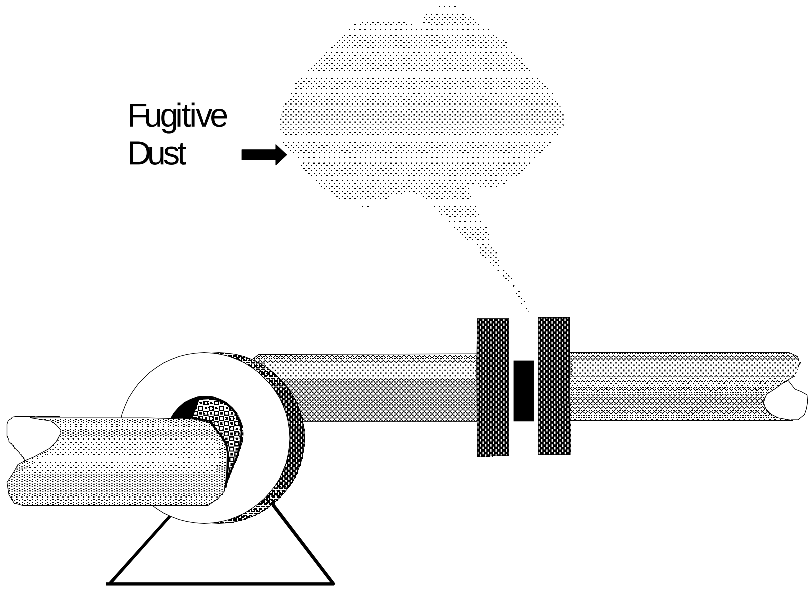
Similar Releases: Continuous emissions of particulate matter from vertical stacks and pipes or conventional point sources and some process vents when emission flow rates and temperature are known. Combustion sources and chemical reactors are typical emission sources that may emit such pollutants through stacks. These releases may also be due to a process failure such as a rupture disk release or failure of control equipment.

Continuous Fugitive/Windblown Dust Emissions - 1.2



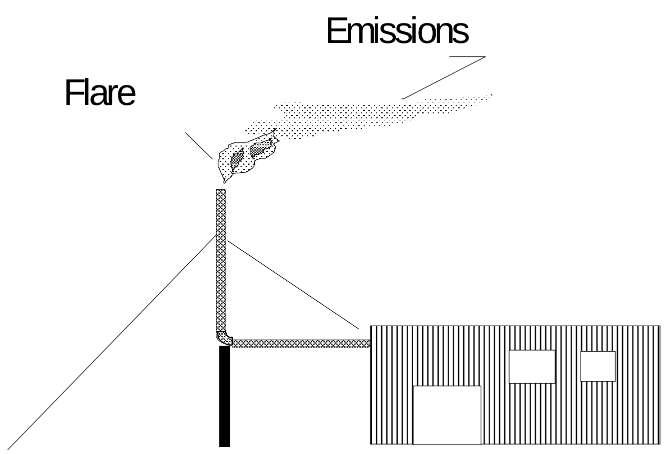
Similar Releases: Any fugitive dust from process losses, generated by mechanical action in material handling or windblown dust. Such emissions tend to originate from a surface or a collection of small poorly defined point sources.

Particulate Releases from Ducting/Connector Failures - 1.3



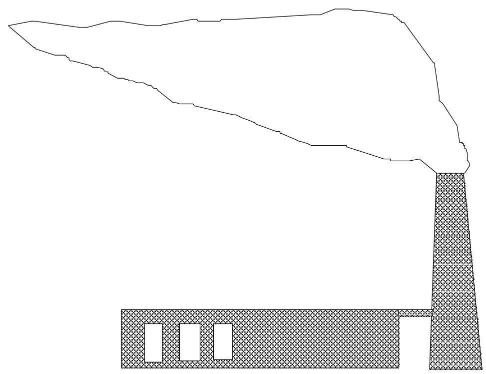
Similar Releases: Instantaneous bursts of particulates due to duct failure (e.g., pneumatic conveyor line failures), line disconnection, isolation joint failure, or other types of equipment openings.

Continuous Flared Stack Emissions - 2.1



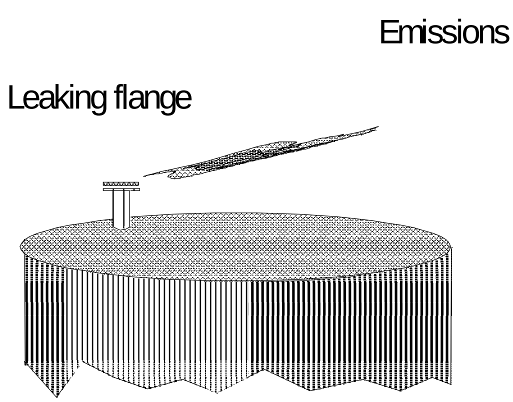
Similar Releases: Flares are used as a control device for a variety of sources. As such flares must comply with requirements specified in 40 CFR 60.18.

Continuous Release from Stacks, Vents, Conventional Point Sources - 2.2



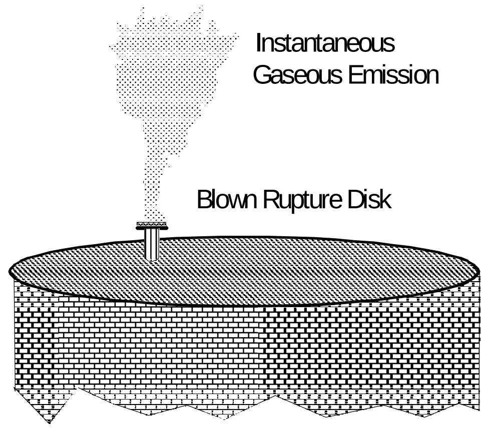
Similar Releases: Continuous emissions of a gas from vertical stacks and pipes or conventional point sources and some process vents when emission flow rates and temperature are known. Combustion sources and chemical reactors are typical emission sources that may emit such pollutants through stacks. These releases may also be due to a process failure such as a rupture disk release or failure of control equipment.

Continuous Gaseous Leaks from Reservoir - 2.3



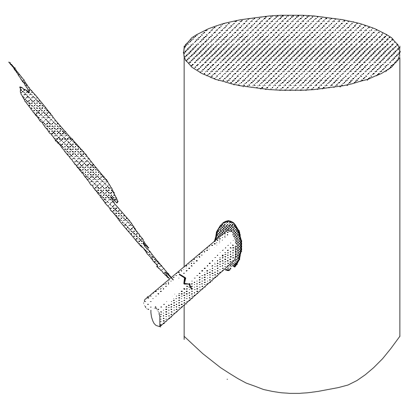
Similar Releases: Continuous release of a gas (at constant pressure and temperature) from a containment (reservoir) through a hole or opening. Possible applications include a gas leak from a tank, a (small) gas leak from a pipe, or gas discharge from a pressure relief valve mounted on a tank.

Instantaneous Gaseous Leak from Reservoir - 2.4



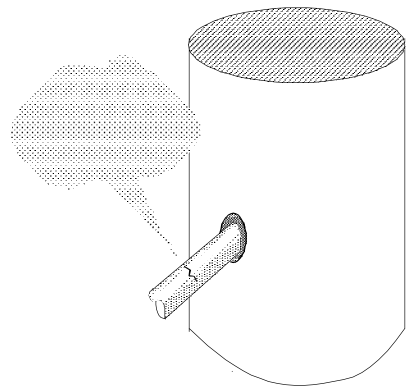
Similar Releases: Instantaneous release of a gas (at constant pressure and temperature) from a containment (reservoir) through a hole or opening. Possible applications include a gas leak from a tank, a (small) gas leak from a pipe, or gas discharge from a pressure relief valve mounted on a tank.

Continuous Leaks from a Pipe Attached to a Reservoir - 2.5



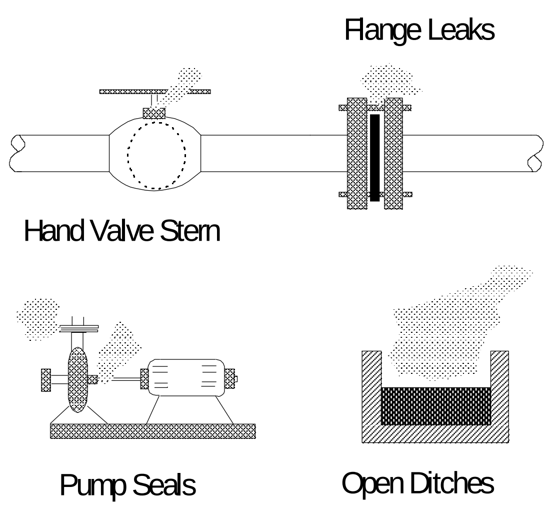
Similar Release: Continuous release of a gas (at constant pressure and temperature) from a containment (reservoir) through a long pipe.

Instantaneous Leaks from a Pipe Attached to a Reservoir - 2.6



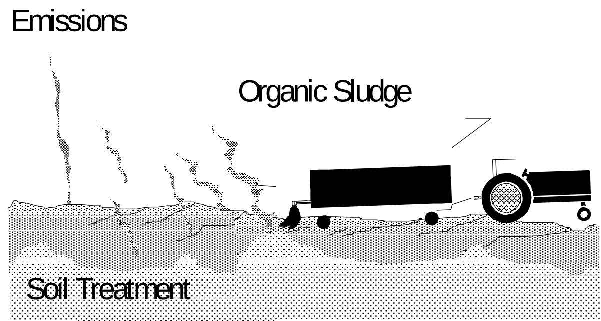
Similar Release: Instantaneous release of a gas (at constant pressure and temperature) from a containment (reservoir) through a long pipe.

Continuous Multiple Fugitive Emissions - 2.7



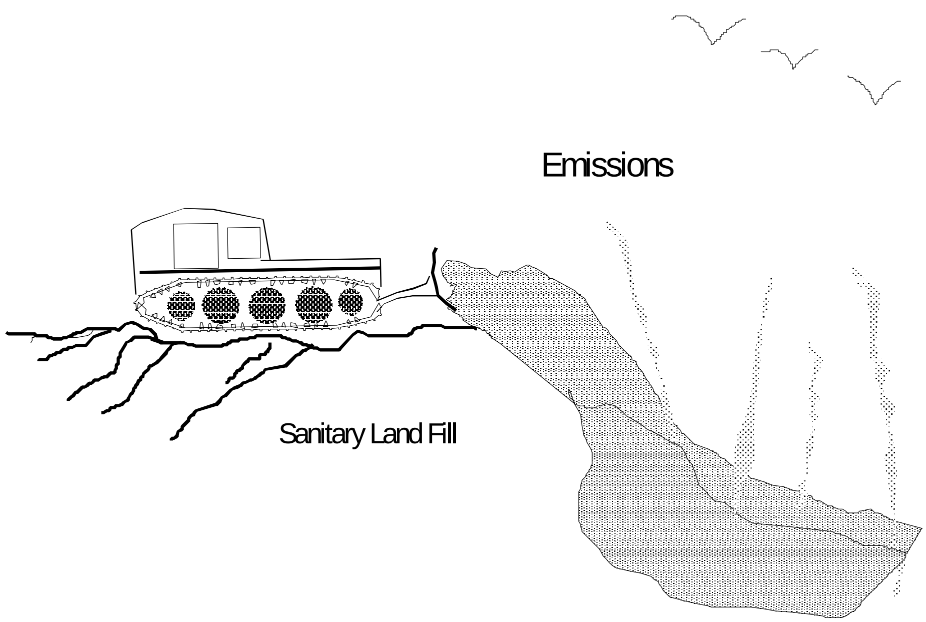
Similar Releases: Releases from any continuous area or volume source where the emissions are uniformly released over the area or the area represents a collection of small sources poorly defined in terms of location (e.g., multiple vents on large manufacturing buildings, fugitive VOC sources in refineries or chemical process manufacturing plants).

Continuous Emissions from Land Treatment Facilities - 2.8

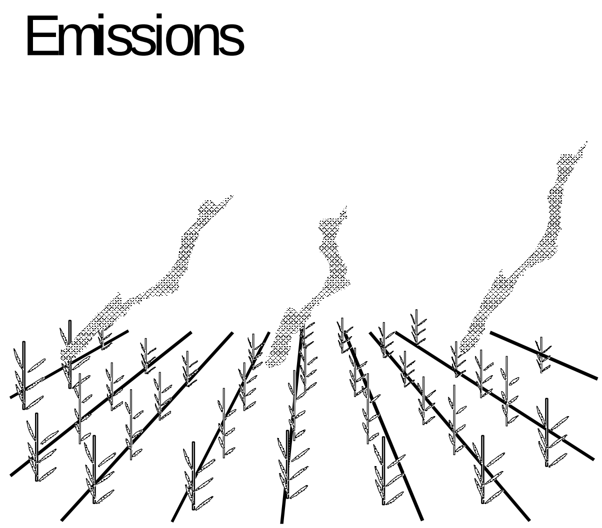


<u>Similar Releases:</u> Landfarms; ground level application of sludge (containing volatile organic material in oil) to soil surface.

Continuous Emissions from Municipal Solid Waste Landfills - 2.9

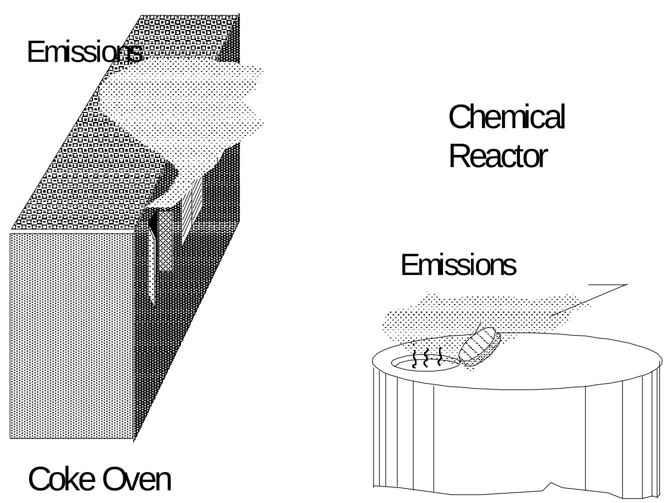


<u>Similar Releases:</u> None. Emission rates applicable to municipal solid waste landfills only.



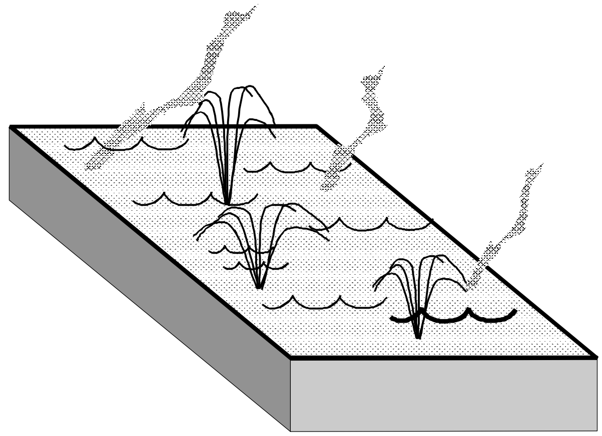
<u>Similar Releases:</u> Emissions resulting from the volatilization of pesticides or herbicides applied to open fields.

Instantaneous Discharges from Equipment Openings - 2.11



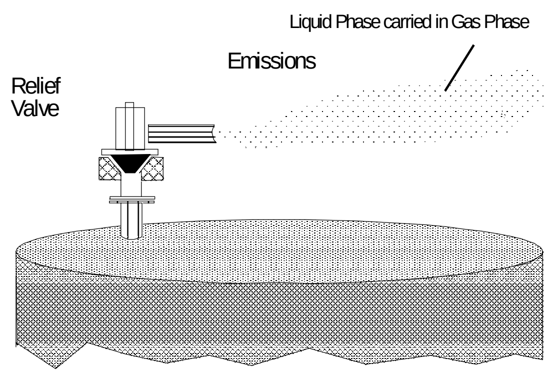
<u>Similar Releases:</u> Any puff or burst type release with short duration emissions resulting from the opening of equipment after processing (e.g., coke ovens or chemical reactors), from routine sampling of product processing or gaseous emissions from disconnected lines.

Continuous Evaporation from Surface Impoundments (Lagoons) - 3.1



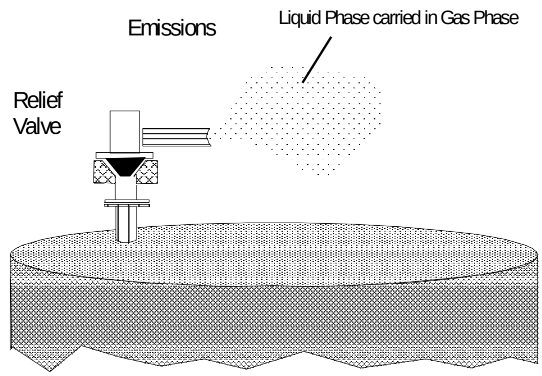
Similar Releases: Waste lagoons and other impoundments with emissions resulting from the evaporation of volatile chemicals from liquid mixtures with biological activity.

Continuous 2-Phase Saturated Liquid from Pressurized Storage - 3.2



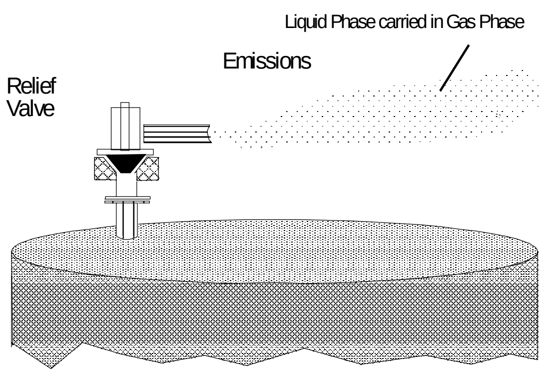
Similar Releases: Continuous release of a pressurized liquid stored under saturated conditions. The release occurs (at constant pressure and temperature) from the containment (reservoir) through a hole or opening; a provision is made for the effect of a pressure drop (piping) between the tank and the hole or opening. Possible applications include a saturated liquid leak from a pressurized tank or a saturated liquid leak from a pipe.

Instantaneous 2-Phase Saturated Liquid from Pressurized Storage - 3.3



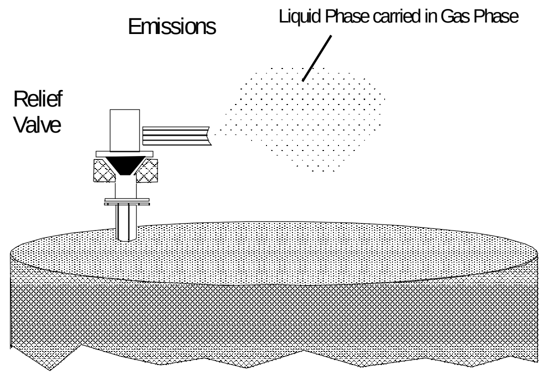
Similar Releases: Instantaneous release of a pressurized liquid stored under saturated conditions. The release occurs (at constant pressure and temperature) from the containment (reservoir) through a hole or opening; a provision is made for the effect of a pressure drop (piping) between the tank and the hole or opening. Possible applications include a saturated liquid leak from a pressurized tank or a saturated liquid leak from a pipe.

Continuous Subcooled Liquid from Pressurized Storage - 3.4



Similar Releases: Continuous release of pressurized liquid stored below its saturation pressure. The release occurs (at constant pressure and temperature) from a containment (reservoir) through a hole or opening; a provision is made for the effect of a pressure drop (piping) between the tank and the hole or opening. Possible applications include a subcooled liquid leak from a pressurized tank or a subcooled leak from a pipe.

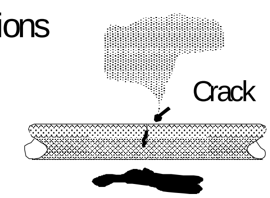
Instantaneous Subcooled Liquid from Pressurized Storage - 3.5



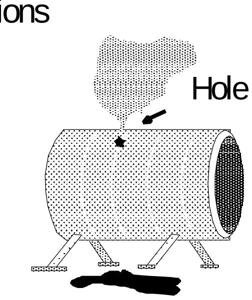
<u>Similar Releases:</u> Instantaneous release of pressurized liquid stored below its saturation pressure. The release occurs (at constant pressure and temperature) from a containment (reservoir) through a hole or opening; a provision is made for the effect of a pressure drop (piping) between the tank and the hole or opening. Possible applications include a subcooled liquid leak from a pressurized tank or a subcooled leak from a pipe.

Continuous High Volatility Liquid Leaks - 3.6

Pipe

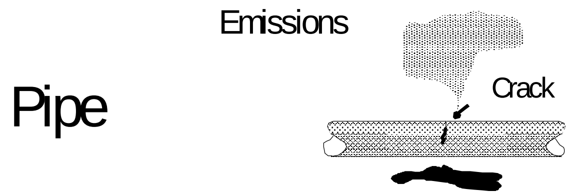


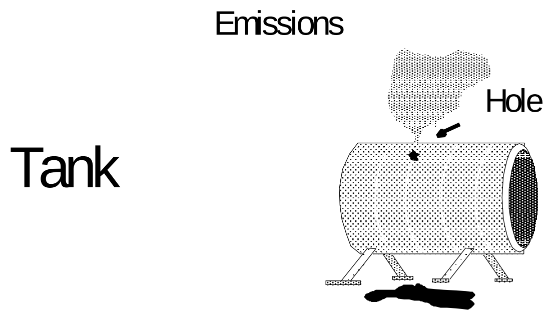
Tank



<u>Similar Releases:</u> Continuous release of high volatility liquid (at constant temperature and pressure) from a containment (reservoir) through a hole or opening. Possible applications include a (high volatility) liquid leak from a tank or a liquid leak from a pipe (when the ratio of the hole diameter to the pipe diameter is less than 0.2).

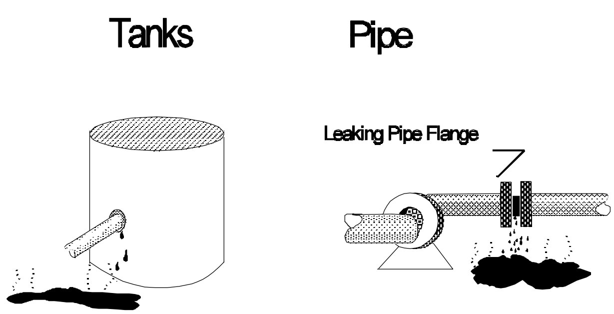
Instantaneous High Volatility Liquid Leaks - 3.7



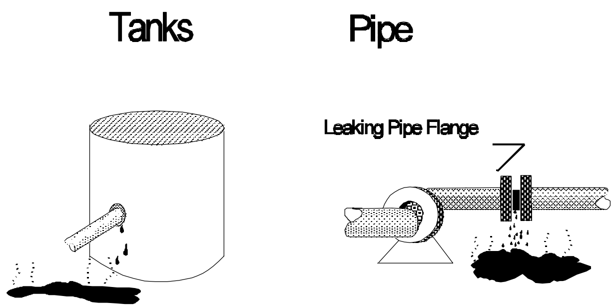


<u>Similar Releases:</u> Instantaneous release of high volatility liquid (at constant temperature and pressure) from a containment (reservoir) through a hole or opening. Possible applications include a (high volatility) liquid leak from a tank or a liquid leak from a pipe (when the ratio of the hole diameter to the pipe diameter is less than 0.2).

Continuous Low Volatility Liquid Leaks - 3.8

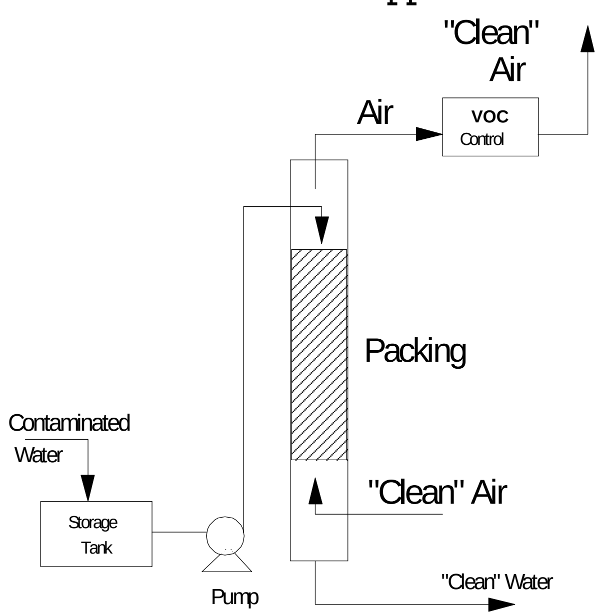


<u>Similar Releases:</u> Continuous release of liquid whose normal boiling point is above ambient temperature. A low volatility material stored at moderate to low pressure (and where the boiling point is above storage temperature) will typically be released as a liquid and form a pool or puddle on the ground. The (conservative) assumption is that the liquid evaporates at the same rate it is spilled (except when the liquid is confined by a bund dike from which liquid does not overflow). Possible applications include a (low volatility) liquid leak from a tank or a pipe.



Similar Releases: Instantaneous release of liquid whose normal boiling point is above ambient temperature. A low volatility material stored at moderate to low pressure (and where the boiling point is above storage temperature) will typically be released as a liquid and form a pool or puddle on the ground. The (conservative) assumption is that the liquid evaporates at the same rate it is spilled (except when the liquid is confined by a bund dike from which liquid does not overflow). Possible applications include a (low volatility) liquid leak from a tank or a pipe.

4.1 Air Strippers



Similar Releases: None.

2.4 Determining Maximum Short-Term Ground Level Concentration

2.4.1 Dispersion Models used in TSCREEN

Maximum short-term ground level concentrations in TSCREEN are based on three current EPA screening models (SCREEN, RVD, and PUFF) and the Britter-McQuaid screening model. All four models are embedded in the TSCREEN model. SCREEN is a Gaussian dispersion model applicable to continuous releases of particulate matter and non-reactive, non-dense gases that are emitted from point, area, and flared sources. The SCREEN model implements most of the single source short-term procedures contained in the EPA screening procedures document (EPA, 1988c.) This includes providing estimated maximum ground-level concentrations and distances to the maximum based on a pre-selected range of meteorological conditions. In addition, SCREEN has the option of incorporating the effects of building downwash. The RVD model (EPA, 1989) provides short-term ambient concentration estimates for screening pollutant sources emitting denser-than-air gases and aerosols through vertically-directed jet releases. The model is based on empirical equations derived from wind tunnel tests and estimates the maximum ground level concentration at plume touchdown at up to 30 downwind receptor locations. The PUFF model (EPA, 1982) is used where the release is finite but smaller than the travel time (i.e., an instantaneous release.) This model is based on the Gaussian instantaneous puff equation and is applicable for neutrally buoyant non-reactive toxic air releases. The Britter-McQuaid model (1988) provides an estimate of dispersion of denser-than-air gases from area sources for continuous (plume) and instantaneous (puff) releases. Further discussion on model assumptions is given in Chapter 5.0.

2.4.2 Dispersion Model Selection

Figure 2-2 shows which screening model is associated with each scenario. In TSCREEN, ambient impacts of releases from pressurized storage vessels (and pipes) or liquid releases are evaluated using the following test. The release density ρ_2 (kg/m^3) is compared with ambient density, ρ_{air} (kg/m^3). If the release density is more than ambient density (i.e., $\rho_2/\rho_{air} > 1$), then the release is considered denser-than-air. For denser-than-air releases (both continuous and instantaneous), TSCREEN uses the RVD model if the release is a vertically-directed jet and the Britter-McQuaid model for all other releases. For releases that are considered passive (i.e., $\rho_2/\rho_{air} \leq 1$), TSCREEN uses the SCREEN model for a continuous release and the PUFF model for an instantaneous release.

If the release density is greater than ambient density (i.e., $\rho_2/\rho_{air} > 1$), a further determination of the importance of denser-than-air behavior based on contaminant release rate and the ambient wind speed is made after calculating the Richardson number (see below). Since for many applications (e.g., planning analyses) the actual wind speed is not known, this method is not used in TSCREEN (version 3.0). The following shows how the user may approach the problem.

Figure 2-2. Model Selection